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Foveal task effects on same-different judgments in the visual periphery

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An attempt was made to examine the extent to which the presence of a foveal stimulus affects same-different judgments regarding the horizontal-vertical orientation of two lines located in peripheral vision. The results of the study indicated that accuracy in reporting peripheral visual stimuli is determined not only by the nature of those stimuli, but also by whether other stimuli are presented foveally. The simultaneous presence of another stimulus in foveal vision reduces accuracy in reporting peripheral stimuli, independent of instructions to ignore, detect, or identify the foveal stimulus.

Most visual events occur simultaneously across wide areas of the visual field. Some of these events occur in the foveal or central region of vision, while others take place in the peripheral or noncentral areas of the visual field. However, much laboratory research on vision has been designed to examine processing of a limited number of visual events, presented either foveally or peripherally. Only recently have researchers begun to ask how foveal and peripheral events might interact. Specifically, studies have begun to examine the extent to which the presence of a foveal event might affect the processing of a peripheral event.

The research that is available does suggest that such an interaction exists: Namely, when subjects are required to respond to a foveal stimulus, their ability to utilize peripheral visual information is decreased. For example, subjects have more difficulty identifying a peripheral stimulus when other stimuli are simultaneously presented to the fovea than when the peripheral stimulus is presented alone (Ikeda & Takeuchi, 1975). Similarly, when subjects are asked to follow a centrally moving fixation dot (Liebowitz & Appelle, 1969) or to count the number of central fixation points (Webster & Haslerud, 1964), visual processing of peripherally located stimuli suffers.

It appears, then, that when subjects are asked to respond simultaneously to foveal and peripheral events, performance levels on the peripheral events are reduced. Such a finding, however, raises the question of whether it is the requirement of responding to the foveal stimulus or simply its presence that leads to this decrement in performance on peripheral stimuli.

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It has been suggested that the presence of the foveal stimulus is the important factor, since the presence of foveal noise stimuli in the visual field interferes with the ability of subjects to detect similarities among relevant foveal and peripheral items (Mackworth, 1965). Similarly, the ability to identify a brief peripheral stimulus is reduced when a second stimulus is simultaneously presented to the fovea, independent of whether the subject is told to ignore the foveal stimulus or to identify it (Holmes, Cohen, Haith, & Morrison, 1977). These results indicate that it is the mere presence of foveal stimuli, and not the requirement that they be responded to, that produces the commonly observed decrements in response to peripheral stimuli. Moreover, these results suggest that the decrement in performance on peripheral items occurs because subjects attend to and process the central item, at least to some degree.

This study was designed to assess the extent to which a foveal stimulus was processed under conditions where subjects were instructed to ignore it. This assessment was made by comparing the performance of subjects on a peripheral stimulus task when they were presented with a variety of foveal task conditions. In particular, performance on a peripheral same-different task was assessed when there was no foveal stimulus, a foveal stimulus that subjects were instructed to ignore, a foveal stimulus that subjects were instructed to detect, or a foveal stimulus that subjects were instructed to identify. It was assumed that if subjects were able to control the extent to which they processed the foveal stimulus, then performance on the peripheral same-different task would decline systematically as subjects were required to expend more processing attention on the foveal stimulus. On the other hand, if subjects were not able to control the extent to which they processed the foveal stimulus, then performance on the peripheral task would differ only as a function of whether or not a foveal stimulus was present.

METHOD

Subjects

Ten adult subjects with normal or corrected-to-normal vision participated in this study. All subjects were volunteers and were not paid for participation.

Materials

All stimuli were presented on a cathode-ray tube (CRT) with a P24 phosphor in a VR14 display console with a display luminance of about 1 mL under steady-state conditions. The CRT was driven by a Digital Equipment Corporation PDP-8/e computer located in the next room (see Mayzner, Tresselt, & Helfer, 1967, for a full description of this apparatus).

In all conditions, the same peripheral stimuli were employed. These peripheral stimuli consisted of two lines 1 deg, 21 min of visual angle (va) in length (horizontal or vertical) presented at 5.5 deg va from the center of the visual field and located in two of the four possible diagonal locations (±45 deg and ±135 deg from the vertical). The two peripheral line stimuli were exposed for 10 msec and were followed after 120 msec by four star-shaped masking stimuli (with line length of 1 deg, 21 min va) of 500-msec duration in the four possible peripheral locations. These exposure and postexposure time intervals were selected by two criteria: (1) To prevent subjects from performing at ceiling levels on the peripheral same-different task when there was no central stimulus present; and (2) to maintain the total exposure and postexposure time below that necessary to make an eye movement.

While the nature of the peripheral stimuli remained constant across all conditions, the five experimental task conditions did differ in the nature of the foveal stimulus. In one condition (no foveal stimulus), there was no central stimulus. In the three foveal target conditions (foveal stimulus ignored, foveal detection, and foveal identification), a single foveally located target stimulus (either a "+" or an "X") of 1 deg, 21 min va in line length appeared simultaneously with the peripheral line stimuli for 10 msec. After an interstimulus interval of 70 msec, a star-shaped foveal mask (also of 1-deg, 21-min va line length) appeared for 550 msec. The interval between the offset of the foveal target stimulus and the onset of the foveal mask was selected in pilot work by the criterion that subjects should perform at 75% correct on identification of the foveal target stimulus in the absence of the peripheral task. The final condition (foveal mask) was employed as a control condition: Namely, to assess the effects of the foveal mask per se. The trials of the foveal mask condition therefore were identical to the three foveal target conditions except that no target stimulus appeared prior to the foveal mask.

Procedure

In all conditions, subjects were required to make same-different judgments regarding the orientation of the two peripheral line stimuli. The same-different judgment was used to avoid the problems faced during earlier research in attempting to insure that subjects actually fixate at the center of the screen. This problem was avoided in this study by the presentation of two peripheral stimulus lines in any of four locations on each trial. Subjects were instructed that they would be most likely to see both lines if they fixated at the center of the screen.

Although the response to the peripheral lines was constant in all conditions, in each of the three foveal target stimulus conditions, subjects were instructed to respond to the foveal stimulus in a different manner. In the foveal stimulus ignored condition, subjects were instructed to ignore the foveal target stimulus (i.e., either "+" or "X") and to report only whether the two peripheral lines were the same or different in orientation. In the foveal detection condition, subjects were instructed to report whether the peripheral lines were the same or different and whether or not a foveal target stimulus was present. In the foveal identification condition, subjects were instructed to report whether the peripheral lines were the same

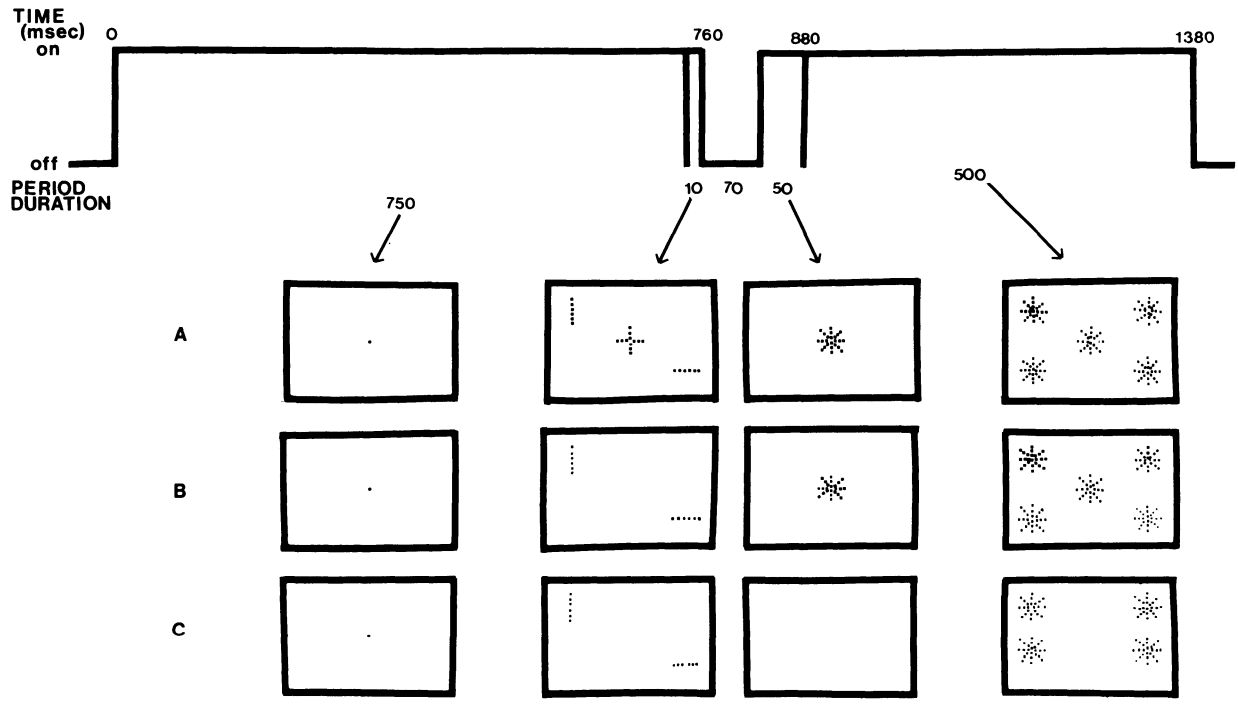

Figure 1. An illustration of stimuli presented and the time parameters involved in conditions utilizing (A) a foveal target stimulus, (B) a foveal mask only, and (C) no foveal stimulus.

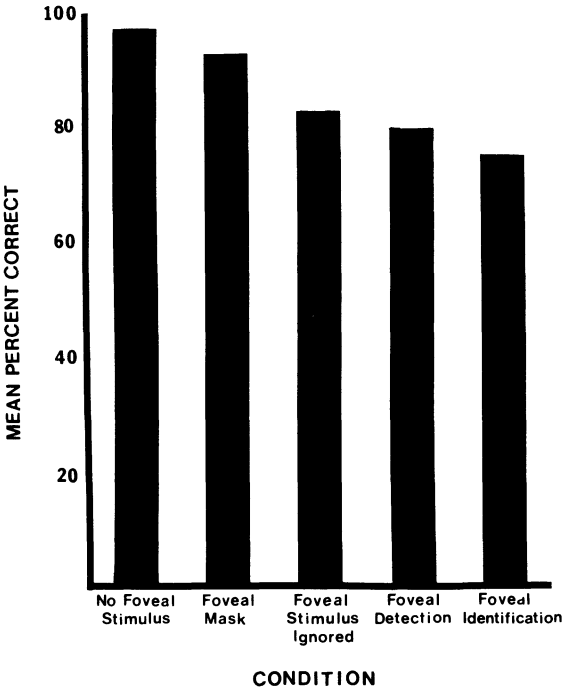

Figure 2. Mean percent correct on peripheral same-different judgments as a function of foveal stimulus and task condition.

or different and to identify the foveal target stimulus (i.e., either a "+" or an "X"). Subjects were not instructed regarding order of report for foveal and peripheral tasks.

Each subject received 60 trials in each condition: Of these, 48 trials represented all possible combinations of two foveal stimuli ("+" or "X") with four peripheral stimulus pairs (–, –; –, |; |, |; |, –) by six possible location combinations for the two peripheral stimuli (four positions taken two at a time). In addition, 12 foveal blank trials were constructed for the foveal detection task; these trials were also included in the other conditions in order to insure condition equality, but were not included in the data analysis in any condition. Each subject participated in all five conditions and thus received a total of 300 trials (60 trials per stimulus condition). Condition order was counterbalanced across subjects by a Latin-square design.

Testing of each subject was completed over five sessions of approximately 1 h each (one session per experimental condition). Each session began with 12 practice trials that were not included in data analysis.

On any particular trial, the subject signaled the experimenter in the computer room via an intercom when he was ready to begin. The experimenter then signaled the subject and initiated the trial. Each trial began with the appearance of a fixation dot for 750 msec, followed by the test stimulus. At the completion of each trial, subjects recorded their own responses and signaled to the experimenter when they were ready for the next trial. Subjects were not given feedback regarding the accuracy of their responses.

RESULTS

Percent correct same-different judgments on the peripheral line stimuli were calculated for each subject's performance in each condition. The two conditions that did not contain a foveal target stimulus produced high performance in the same-different peripheral task. In sharp contrast, the three foveal target conditions produced relatively poor performance in the same-different peripheral task.[1] A repeated-measures analysis of variance revealed that this difference among conditions was very significant [$F(4,36) = 9.53$, $p < .001$]. A Newman-Keuls test further revealed that performance in the two conditions that did not contain a foveal target stimulus (i.e., no foveal stimulus and foveal mask) differed significantly from performance in all three conditions in which a foveal target was present ($p < .05$). Performance in the three foveal target stimulus conditions (i.e., foveal stimulus ignored, foveal detection, and foveal identification) did not differ significantly ($p > .05$), and performance in the two conditions that did not contain a foveal target stimulus (i.e., no foveal stimulus and foveal mask) did not differ significantly ($p > .05$).

DISCUSSION

In short, a subject's accuracy in peripheral same-different judgments was best predicted by whether or not a foveal target stimulus was also simultaneously presented. Furthermore, performance on the peripheral same-different task was not significantly affected by instructions to the subjects (and, one may assume, intentions of the subjects) to ignore, detect, or identify the foveal stimulus. These results again support the view that the ability to identify briefly presented visual stimuli is impaired when a foveal stimulus is also present, regardless of instructions to ignore the foveal stimulus. This suggests that the foveal stimulus is processed nonetheless. Moreover, the foveal stimulus appears to be processed in some depth, since only slight insignificant differences were obtained among the different foveal target conditions.

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NOTE

1. D′ scores were also calculated and produced substantially similar results as percent correct. Similarly, in conditions where subjects were required to detect or identify the foveal target stimulus, performance on the peripheral task did not differ as a function of whether the foveal task was correct or incorrect.

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